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(21) International Application Number: PCT/FI94/00478 (22) International Filing Date: 21 October 1994 (21.10.94) (30) Priority Data: 934759 27 October 1993 (27.10.93) FI (71) Applicant (for all designated States except US): NOKIA TELECOMMUNICATIONS OY [FI/FI]; Mäkkylän puistotie 1, FIN-02600 Espoo (FI). (72) Inventors; and (75) Inventors/Applicants (for US only): KESKITALO, Ilkka [FI/FI]; Rantapolku 1 N 2, FIN-90940 Jääli (FI). KIEMA, Arto [FI/FI]; Erkkilänkatu 8 as. 2, FIN-24280 Salo (FI). SAVUSALO, Jari [FI/FI]; Valtatie 73 A 16, FIN-90500 Oulu (FI). JOLMA, Petri [FI/FI]; Hintantie 78 A 3, FIN-90650 Oulu (FI). (74) Agent: TEKNOPOLIS KOLSTER OY; c/o Oy Kolster Ab, Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).		(81) Designated States: AU, CN, DE, GB, JP, NO, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> <i>In English translation (filed in Finnish).</i>
(54) Title: METHOD FOR ELIMINATING MULTIPLE-ACCESS INTERFERENCE AND A MOBILE STATION		
(57) Abstract <p>The invention relates to a mobile station and a method for eliminating multiple-access interference in a CDMA cellular radio system having cells (21) each comprising at least one base station (20) communicating (25) with mobile stations (24) residing in the cell and informing the mobile stations of at least one spreading code used in a neighbouring cell (23), the mobile stations measuring the code phase and power level of a channel (26) of the neighbouring cell using the known spreading code. To reduce the effect of multiple-access interference, the signal received at the mobile station (24) is utilized in the detection of the desired signal by using the code phase and power level of the measured channel (26) using the known spreading code of the neighbouring cell.</p>		

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Method for eliminating multiple-access interference
and a mobile station

5 The invention relates to a method for
eliminating multiple-access interference in a CDMA
cellular radio system having cells each comprising at
least one base station communicating with mobile
stations residing in the cell and informing the mobile
10 stations of at least one spreading code used in a
neighbouring cell, the mobile stations measuring the
code phase and power level of a channel of the neigh-
bouring cell using the known spreading code.

CDMA is a multiple access method based on the
spread spectrum technique, and it has been applied
15 recently in cellular radio systems together with the
earlier FDMA and TDMA techniques. CDMA has several
advantages over the earlier techniques, such as
spectral efficiency and simple frequency planning.

In CDMA, the narrow-band data signal of the user
20 is multiplied to a relatively broad band with a
spreading code having a considerably broader band than
the data signal. Known test system use bandwidths such
as 1.25 MHz, 10 MHz and 25 MHz. The multiplication
spreads the data signal over the entire available
25 band. All users transmit on the same frequency band
simultaneously. A spreading code is assigned to each
connection between a base station and a mobile sta-
tion, and the signals of different users can be dis-
tinguished from each other in the receivers on the
30 basis of the spreading code of each user.

Correlators provided in the receivers are syn-
chronized with the desired signal, which is recognized
on the basis of the spreading code. In the receiver,
the data signal is restored to the original band by
35 multiplying it again with the same spreading code as

at the transmission stage. In an ideal case, signals multiplied with some other spreading code do not correlate and are not restored to the narrow band. From the viewpoint of the desired signal, they thus appear
5 as noise. One attempts to select the spreading codes of the system in such a way that they are orthogonal with respect to each other, i.e. do not correlate with each other.

In a typical cellular radio environment, signals
10 between a mobile station and a base station propagate over several paths between a transmitter and a receiver. This multipath propagation is mainly due to reflections of the signal from the surrounding surfaces. Signals that have propagated over different
15 paths arrive at the receiver at different times due to their different propagation time delays. CDMA differs from the conventional FDMA and TDMA in that the multipath propagation can be utilized in signal reception. A so-called rake receiver comprising one or more rake
20 branches or correlators is a widely used receiver solution in CDMA. Each correlator is an independent receiver unit, the function of which is to assemble and demodulate one received signal component. The implementation of a rake branch is described more
25 closely in *Modern Communications and Spread Spectrum*, Chapter 12, G. Cooper, C. McGillem, McGraw-Hill, New York 1986. A CDMA receiver typically comprises a separate impulse response measuring equipment, the function of which is to search out different signal
30 components transmitted with a desired spreading code, and detect the phases of the signal components. Each rake branch or correlator can be controlled so that it will be synchronized with a signal component propagated over a different path. In the conventional CDMA
35 receiver, the signals of the correlators are combined

in an advantageous way, thus obtaining a signal of high quality. The signal components received by the correlators may have been transmitted from one base station, or in the case of macrodiversity, from several base stations.

Generally speaking, the spreading codes are not orthogonal at all values of the delay. Accordingly, signals delayed in different ways cause interference in the signal detection. Such interference caused by different users to one another is called multiple-access interference.

The base station transmits to all mobile stations residing within its area on the same frequency band. The same frequency band is typically also used in adjacent cells. To minimize multiple-access interference, the spreading codes used by one and the same base station within the cell are attempted to be selected so that they are orthogonal with respect to each other. Power control is also used to eliminate the effect of multiple-access interference within a cell.

In the CDMA cellular radio system, it is possible to use a channel called a pilot channel. The pilot channel is a data-unmodulated signal transmitted with a certain spreading code. Thus it contains no data. The pilot channel is transmitted on the same frequency band on which the actual traffic channels are located; the pilot channel can be distinguished from the traffic channels only on the basis of the spreading code. The pilot channel is used e.g. in power measurements and in generating a coherent phase reference. The base station may also inform the mobile stations moving within its area about the spreading codes of the pilot channels of the base stations of neighbouring cells. In this way, the mobile stations

are able to identify the transmission of the neighbouring cells. This can be utilized in the handover procedure.

5 When a mobile station approaches the edge of the coverage area of its dedicated base station, a signal from a neighbouring base station, which is within the same frequency range as the transmission of the dedicated base station, begins to appear as an increasingly strong interference in the receiver of the mobile station. This interference is particularly disadvantageous, as the spreading codes used in the neighbouring cells are not necessarily fully orthogonal with the codes used in the mobile station's own cell. Moreover, the power control of the base station of the neighbouring cell, if there is any in use, does not take the adjacent cells into account.

10 The object of the present invention is to reduce the effect of multiple-access interference in a situation where a desired signal from the dedicated base station is at minimum and interference from the neighbouring cells is at maximum, i.e. within the boundary area of the cells.

15 This is achieved by means of a solution according to the method described in the preamble, which is characterized in that the code phase and power level of the measured channel using the known spreading code of the neighbouring cell are utilized in the detection of the desired signal from the received signal at the mobile station.

20 The invention also relates to a mobile station intended for use in a CDMA cellular radio system having cells each comprising at least one base station communicating with mobile stations residing in the cell, the mobile station having means for measuring the code phase and power level of a channel using a

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known spreading code of a base station in a neighbouring cell. The mobile station according to the invention is characterized in that the mobile station comprises means for detecting a desired signal from a received signal by utilizing the code phase and power level of the measured channel using the known spreading code of the neighbouring cell.

As already mentioned, a CDMA receiver is typically implemented by the rake technique, where the receiver comprises several correlator branches which can synchronize with signal components propagated in different ways. In the solution according to the invention, however, correlator branches are utilized in eliminating interference. All of the correlators are not synchronized with a signal propagated over several paths from the base station to the antenna of the mobile station and using the base station's own spreading code; instead, one or more of the correlators are synchronized with a signal transmitted from the base station of a neighbouring cell and using a known spreading code assigned to another connection. In this way, the receiver is able to utilize information about the code phases and power levels of the signals in the detection of the desired signal.

The method according to the invention is particularly advantageous when the CDMA system uses complementary codes as spreading codes. In such a system, there occurs no intra-cell multiple-access interference, as all of the spreading codes used within the cell are orthogonal with respect to each other. All of the interference thus originates from the neighbouring cells.

A further advantage of the method according to the invention is that the base station can reduce the transmission power of a signal to a mobile station

without deteriorating the quality of the connection, as the invention allows the quality of the signal of the mobile station to be improved in areas where the mobile station is at the greatest distance from the base station. In this way, the adjacent cells are interfered with to a lesser extent than what has been possible previously.

In the following the invention will be described more closely with reference to the examples of the attached drawings, where

Figure 1 shows a diagram illustrating a portion of a cellular network where the method according to the invention is applicable;

Figure 2 illustrates a situation where a mobile station is located close to the edge of a cell; and

Figure 3 shows an example of an implementation of the mobile station according to the invention.

Figure 1 is a diagram illustrating a portion of a CDMA cellular radio system. Two base stations BTS1 and BTS2 are connected to a base station controller BSC by digital transmission links 11. The coverage area of one base station BTS typically forms one radio cell. The base station controller communicates with the other parts of the cellular network and with a fixed network.

Figure 2 shows a situation where a mobile station 24 in communication with the base station 20 servicing a cell 21 has moved to the boundary area between cells 21 and 23. Cell 23 is serviced by the base station 22. In the following, one preferred embodiment of the invention will be described by way of example with reference to the situation shown in Figure 2, where there is a single neighbouring cell, assuming that the system utilizes a pilot channel, without, however, limiting the invention to this

embodiment.

On approaching the edge of cell 23, the mobile station experiences an increase in the interference level of the connection when it is receiving a signal from its dedicated base station. This multiple-access interference is caused by the base station 22 servicing cell 23, the transmission of the base station 22 taking place at the same frequency as in the mobile station's own cell 21. The spreading codes used in the neighbouring cells are not fully orthogonal with respect to each other, which results in increased level of interference in a signal received at the receiver of the mobile station with its own spreading code. This phenomenon is particularly apparent when complementary codes are used, in which case there occurs no intra-cell multiple-access interference. On approaching the edge of the cell, a previously noiseless signal deteriorates gradually.

The base station has informed the mobile station about the spreading codes of the pilot channels of some of the neighbouring base stations on one of the control channels assigned to the connection between the base station and the mobile station. The searcher branch of the CDMA receiver of the mobile station searches both for multi-path-propagated signal components transmitted from its dedicated base station with the mobile station's own spreading code and signals provided with the pilot spreading code of the neighbouring base stations.

When the mobile station approaches the edge of cell 23, its searcher branch detects the transmission on the pilot channel of the neighbouring base station, is synchronized with it and measures the power level of the transmission. The mobile station reports these data to its dedicated base station in order that the

handover to the neighbouring base station could be started in due course when the strength of the pilot signal has become high enough.

5 The mobile station is also able to request from
its dedicated base station information about the
spreading codes of the traffic channels of the neighbouring base station for the purpose of interference
elimination. The dedicated base station forwards the
request to the base station controller BSC, which
10 transmits the requested data via the base station to
the mobile station. According to the needs and
capacity, the mobile station can be informed of one or
several spreading codes.

15 If the base stations employ connection-specific
power control, they transmit at unequal transmission
powers on different connections. The greater the
distance from the mobile station to the base station,
the higher the power level on which the base station
is able to transmit a signal addressed to this particular
20 mobile station. Connection-specific power
control is to be preferred when codes used within the
cell do not correlate with each other, such as when
orthogonal codes are used. In addition, connection-
specific power control is to be preferred when the
25 system employs interference elimination, as methods
for interference elimination are the more efficient,
the clearer the differences between the power levels
of the interfering signals. In such a case, the base
station controller may inform the mobile station only
30 of spreading codes used on connections over which the
neighbouring base station uses a high transmission
power level, that is, on connections that interfere
with the mobile station most severely.

35 After having been informed of the spreading
codes of the traffic channels, the searcher branch of

the mobile station is able to detect the code phase of the desired traffic channels and to synchronize with them and, if required, to measure the power level of the transmission. If the connection-specific power control is not in use, it is not necessary to measure the power level, as the power level of the traffic channel can be estimated from the power of the pilot channel already measured.

The mobile station is thus able to receive both the desired signal from its dedicated base station and a signal from a neighbouring base station the spreading code of which it knows. Interference elimination may be an iterative process, so that the number of the rake correlators of the CDMA receiver does not limit the number of signals to be eliminated.

According to a preferred embodiment of the invention, the mobile station calculates the cross-correlation between the received desired signal and interfering signals received with the known spreading codes. The code phases of the signals have to be taken into account in the calculation, as the correlation of the spreading codes with respect to each other depends on the phase difference between them. In addition to this, the result has to be weighted by the received power level of each signal to find out the actual interference caused by each signal in the desired signal.

After having calculated the interference caused by the received signals of the neighbouring cell, the mobile station can eliminate the effect of this interference from the desired signal. To eliminate the interference, each detected interfering signal is again multiplied with the spreading code and subtracted from the received signal, which then can be re-detected. The re-detected signal no longer contains

the interfering signals eliminated as described above.

In addition to the above-described embodiment concerned with the elimination of interference, the invention can also be applied by performing detection
5 in the receiver by taking all of the received signals into account at the same time. The deterministic properties of the signals interfering with the desired signal, such as their power level and code phase, are utilized in the detection.

10 Figure 3 illustrates the configuration of a mobile station MS according to the invention. In the receiving direction the mobile station comprises an antenna 30 which forwards the received signal via radio-frequency sections 31 to an A/D converter 32.
15 The converted signal is applied to RAKE correlators 34a to 34d, each one of which has synchronized with a different signal component originating from one or more base stations. In addition, the A/D-converted signal is applied to a searcher correlator 33, the
20 function of which is to search for signal components transmitted with a desired spreading code by measuring the impulse response of the channel. From the correlators, the signal is applied to means 35 which preferably combine the received signal components and
25 detect the signal. From the combiner the signal is applied to a channel decoder 36 and further via a speech decoder 37 to a loudspeaker 38.

In the transmission direction, a signal from a microphone 39 is applied via a speech coder 40 and a
30 channel coder 41 to spreading coding 42, from which the signal is applied via the RF sections 31 to the antenna 30. The mobile station further comprises means 43 controlling all of the above-mentioned blocks. The means 43 of the mobile station can store information
35 about the spreading codes used on the connections of

neighbouring base stations possibly interfering with the desired signal. This information can be forwarded to the correlators 33, 34a to 34d of the mobile station, which are able to detect the code phase of a
5 signal using the known spreading code of the base station of the neighbouring cell and measure its power level. In the detection of the desired signal, the means 35 can utilize the code phases and power levels of the signals of the neighbouring base station re-
10 ceived by the correlators 34a to 34d.

According to a preferred embodiment of the invention, the means 43 of the mobile station are able to estimate the interference caused by the measured channel of the neighbouring cell by calculating a
15 cross-correlation between the desired signal transmitted from the dedicated base station and the measured signal from the neighbouring base station on the basis of the code phases of the signals and weighting the cross-correlation by the power levels.
20 The mobile station further comprises means 43 for eliminating the calculated interference from the desired signal.

In addition to the above alternatives, the mobile station can also be implemented so that all of
25 the received signals are taken into account at the same time in the detection.

Even though the invention has been described above with reference to the example shown in the attached drawings, it is obvious that the invention is
30 not limited to this example, but it may be modified in various ways within the inventive idea disclosed in the attached claims.

Claims:

1. Method for eliminating multiple-access interference in a CDMA cellular radio system having
5 cells (21) each comprising at least one base station (20) communicating (25) with mobile stations (24) residing in the cell and informing the mobile stations of at least one spreading code used in a neighbouring cell (23), the mobile stations measuring the code
10 phase and power level of a channel (26) of the neighbouring cell using the known spreading code, characterized in that the code phase and power level of the measured channel (26) using the known spreading code of the neighbouring cell are utilized
15 in the detection of the desired signal (25) from the received signal at the mobile station.

2. Method according to claim 1, characterized in that the mobile station (24) detects the desired signal (25) from the received signal by
20 estimating the interference caused by the measured channel using the known spreading code of the neighbouring cell by calculating a cross-correlation between the desired signal (25) transmitted from the dedicated base station and the measured signal (26)
25 from the neighbouring base station on the basis of the code phases of the signals and weighting the cross-correlation with the power levels, and subtracting the calculated interference from the desired signal.

3. Method according to claim 1, characterized in that the spreading code of the
30 neighbouring cell transmitted by the base station (20) to the mobile station (24) is used in one of the traffic channels of the neighbouring cell (23).

4. Method according to claim 1, characterized
35 in that the spreading code of the

neighbouring cell transmitted by the base station (20) to the mobile station (24) is used on the pilot channel of the neighbouring cell (23).

5 5. Method according to claim 1, characterized in that the base station (20) informs the mobile station (24) of the spreading code used in the neighbouring cell (23) on one of the control channels between the base station and the mobile station.

10 6. Method according to claim 1, characterized in that the mobile station (24) is informed only of the spreading codes used in the neighbouring cell (23) which are used on connections possibly interfering with the signal of the mobile station.

15 7. Method according to claim 6, characterized in that the mobile station (24) is informed only of the spreading codes used in the neighbouring cell (23) which are used by mobile stations to which the neighbouring base station
20 transmits at a high power level.

 8. Method according to claim 6, characterized in that a base station controller (BSC) or the like decides which ones of the spreading codes used in the neighbouring cell (23) are indicated to
25 the mobile station (24).

 9. Method according to claim 1, characterized in that information about the spreading codes used in the neighbouring cell (23) is forwarded only to mobile stations (24) requesting such information from their dedicated base station (20).
30

 10. Method according to claim 1, characterized in that information about the spreading codes used in the neighbouring cell (23) is forwarded only to mobile stations (24) with which the connec-

tions using said codes are likely to interfere.

11. Mobile station intended for use in a CDMA cellular radio system having cells (21) each comprising at least one base station (BTS) communicating with mobile stations (24) residing in the cell, the mobile station having means (33) for measuring the code phase and power level of a channel using a known spreading code of a base station (22) in a neighbouring cell (23), characterized in that the mobile station comprises means (35) for detecting a desired signal from a received signal by utilizing the code phase and power level of the measured channel (26) using the known spreading code of the neighbouring cell.

12. Mobile station according to claim 11, characterized in that it comprises means (43) for estimating the interference caused by the measured channel by calculating a cross-correlation between a signal (25) transmitted from the dedicated base station and the measured signal from the neighbouring base station on the basis of the code phases of the signals and weighting the cross-correlation with the power levels, and means (43) for eliminating the effect of the calculated interference from the desired signal.

13. Mobile station according to claim 11, characterized in that the mobile station comprises means (43) for storing information about the spreading codes used on connections of neighbouring cells (23) possibly interfering with the desired signal.

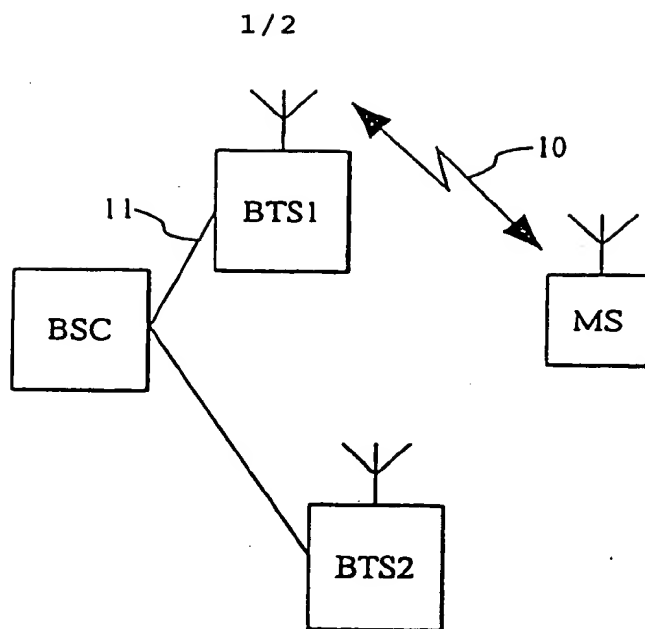


FIG. 1

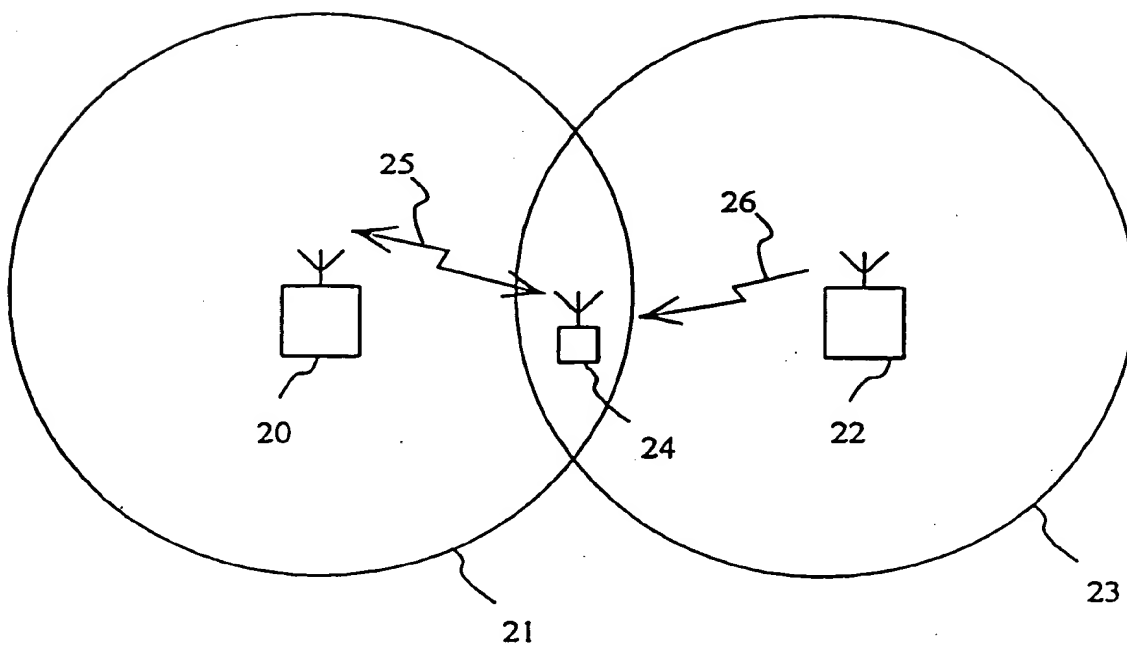


FIG. 2

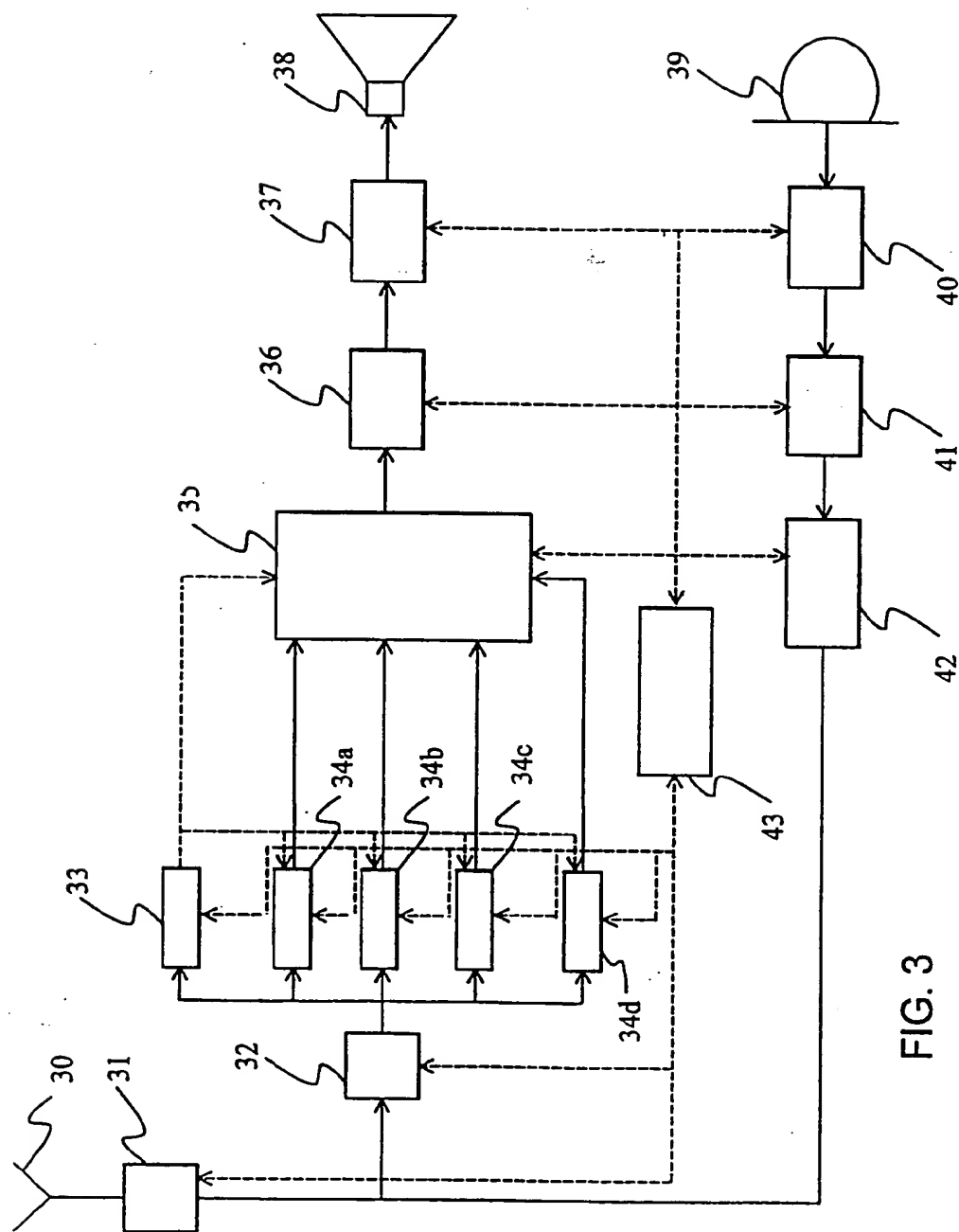


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 94/00478

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04B 7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04B, H04L, H04J, H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	--	1-5
Y	US, A, 5179571 (DONALD L. SCHILLING), 12 January 1993 (12.01.93), column 4, line 2 - line 16; column 14, line 44 - column 15, line 16; column 15, line 54 - column 16, line 6	1-5
A	--	6-10

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

25/02/95

International application No.

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